Juvenile Salmonid Utilization of the Snohomish River Estuary, Puget Sound

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Abstract
Studies of hatchery and wild juvenile salmonid utilization, abundance, distribution and migratory timing in the Snohomish River estuary are being conducted. We examined spatial and temporal patterns of habitat use by wild and hatchery chinook and coho salmon. We will investigate the transferability of these data to research conducted in other large river estuaries in the northwest. This information will help us identify areas for protection and restoration in estuaries throughout the Puget Sound basin. We conducted beach seining in the mainstem and distributary sloughs, and fyke trapping in blind sloughs. Preliminary results indicate temporal patterns of migration in the Snohomish River are similar to those found in other systems. Juvenile salmon were found in all areas of the complex system of mainstem, distributary, and blind sloughs, but fish primarily utilize the mainstem and distributary sloughs as a passageway. While juvenile chinook and coho salmon utilize complex tidal marsh habitats, the numbers of fish found in these systems in the Snohomish River estuary were less than found in comparable habitats in other large river estuaries. Further research will define the extent of utilization of tidal marsh complexes in relation to location in the estuary, availability during tidal cycles, and connectivity to other habitats.

Introduction
In July, 2001, the Northwest Fisheries Science Center (NWFSC) and Tulalip Tribes began a study of juvenile salmonid utilization, abundance, distribution, and migration timing in the Snohomish River estuary of Puget Sound. While our primary focus is on chinook salmon due to imminent recovery needs, information on other salmon species present has also been collected. The overall purpose of this research is to determine spatial and temporal patterns of habitat use by juvenile chinook as they migrate through this estuary. We wish to understand the benefits of specific habitats to juvenile salmon and how changes to the estuary affect the ability of these habitats to support salmon. At a micro-habitat scale, juvenile salmon performance is measured by physical and biological conditions, and ecological interactions within these habitats. At the larger landscape scale, the ability of the estuary to support salmon likely depends on the availability, location and connectivity of specific habitats in the estuary.

This is an ongoing research study, and information presented here is preliminary data on chinook and coho salmon from our first year of work. Initially, research efforts have been focused on measuring relative abundance, distribution, and migratory timing of both hatchery and wild juvenile salmonids. We expect in the future to use otolith analyses and mark-recapture techniques to determine life history diversity patterns of chinook salmon as was first described by Reimers (1971). Otolith, DNA, coded-wire tag (CWT) and diet information will also be analyzed and give insight into rearing and migration patterns of juvenile hatchery and wild chinook salmon. We expect this information to help identify restoration and protection activities in Puget Sound estuaries to support recovery of wild chinook salmon populations.

This program complements research being conducted in the estuaries of the Skagit and Nisqually Rivers in Puget Sound, and in coastal Oregon and the Columbia River. In particular, we want to understand how well the relationships being developed as part of the research studies in the Skagit and Salmon (coastal Oregon) river estuaries apply to other systems. The ongoing research in the Snohomish River will provide an opportunity to understand the transferability of results from these other systems, as well as, the ability to collect information not being obtained in these other systems.

Study Area
The Snohomish River estuary is located in central Puget Sound and between the cites of Everett and Marysville. The study area is comprised of the lower 13.0 kilometers of mainstem channel of the Snohomish River, including the three major distributary sloughs (Ebey, Union, and Steamboat sloughs), and the associated marshes and off-channel blind sloughs (Figure 1). Ebey Slough is the longest distributary slough and diverges from the mainstem Snohomish River at riverkilometer (RKM) 13.0 on the right bank. It is 19.95 km long and enters Possession Sound north of the mainstem and other distributary sloughs. Steamboat Slough diverges from the right bank of the mainstem Snohomish River at RKM 6.2, and is 10.0 km long. Steamboat Slough interconnects with Ebey Slough at two locations, RKM 8.5 and 9.7, in the vicinity of Otter Island. Union Slough diverges from Steamboat Slough on the left bank near the divergence of the

mainstem and Steamboat channels. Union Slough is 7.6 km long, interconnects with Steamboat Slough at about RKM 4.0, and flows into Steamboat Slough at RKM 1.4. Salmonids migrate along all four channels to arrive at Possession Sound.

Habitat Descriptions

Mainstem Channel and Distributary Sloughs

The mainstem channel is the dominant stream channel that drains into Possession Sound, and distributary sloughs are secondary channels which branch off of the mainstem and also flow directly into Possession Sound. Salinity levels in the mainstem and distributary sloughs vary seasonally. In late summer (low flow period), salinity levels at the uppermost Snohomish River mainstem channel beach seine site are typically less than 0.5 ppt, while salinity levels at the lower river beach seine sites are over 15 ppt. (Figure 2). During winter and spring high flow periods, salinity levels are below 1 ppt at all sample sites except those nearest the Sound. The mainstem channel and distributary sloughs typically have a grassy or shrubby margin, with undercut or sharp bank drops, and then a gentle sloping mud flat that is exposed midway through the tide cycle. The mainstem, Union, and Steamboat sloughs are primarily diked on both sides, with little or no off-channel marsh habitats available for migrating salmon. There are several dike breaches on Union Slough. Ebey Slough has less diking along its length, and there are multiple breaches in some of the currently unmaintained dikes. Most of the tidal marsh habitat (described below) accessible to juvenile salmonids is off Ebey and Union sloughs.

Average annual flow of the Snohomish River (measured upstream near the confluence of the Snoqualmie and Skykomish rivers) is 273 cm/s (9,625 cf/s), with a maximum flow of 4,248 cm/s and a minimum flow of 21.6 cm/s, during the period of record 1964 - 1998 (USGS 1997, from Haas and Collins 2001). Hydrological modeling indicates that approximately 75% of the flow occurs in the mainstem, while 25% of the flow is routed through Ebey Slough. At the point where Steamboat and Union sloughs diverge from the mainstem, approximately 85% of the flow continues down the mainstem, while 5% flows through Union Slough and approximately 10% flows down Steamboat Slough (Kurt Nelson, personal communication).

Tidal Marsh Habitat Zones

We have followed the habitat classification method of Cowardin et al. (1979) as described in Hayman et al. (1996) to define three habitat zones based on indicator habitat types. These three zones are: estuary emergent marsh (EEM), emergent/forested transition (EFT), and forested riverine/tidal (FRT). Indicator habitats for the EEM zone are low and high saltmarsh vegetation; for the EFT zone are a mosaic of tidally-influenced emergent marsh and scrub shrub habitats; and for the FRT zone are palustrine and riverine forests. Small patches of other non-indicator habitats may be present in any of these zones. Blind tidal channel networks are capillary-like channels within estuarine marshes that fill and drain during a tidal cycle (Haas and Collins 2001). Salinities in the EEM zone sites varies from 4 to 15 ppt, in the EFT zone varies from 0 to 4 ppt, and in the FRT zone varies from 0 - 2 ppt, depending on season and flow levels out of the river.

Ten sample sites were selected for beach seining along the channel margins of the mainstem and distributary sloughs. These sites are distributed both across all four distributary channels, as well as, longitudinally from channel mouths to heads, and stratified by the three vegetation zones (Figure 1). Also, two fyke trap sites were selected in off-channel habitats; one in the lower EEM zone and another upstream in the EFT zone (Figure 1).

Methods

Two blind tidal channels have been sampled in separate tidal marshes, one in the estuarine emergent marsh (EEM) zone, and the other in the emergent forested transition (EFT) marsh zone in order to detect patterns of juvenile salmonid use of these marsh/channel complexes. Fyke net traps were used to trap fish in blind tidal channels. The fyke trap is 3.3 m deep with wings of 0.64 cm stretch mesh that extend from a central fyke cone to the channel edges. A 4 x 8 ft floating live box is attached to the downstream end of the fyke cone. The fyke trap is set at high (slack) tide, and monitored through the outgoing tide until the channel is completely dewatered. All fish in the channel are caught as the water recedes.

Ten sites along the mainstem channel and distributary sloughs in the intertidal lower river and estuary have also been sampled using a beach seine. These 10 sites are stratified in the three habitat zones (EEM, EFT and FRT) described above. Beach seine sampling was typically conducted during the period between high slack tide and low tide, during daylight hours. The beach seine is 3 m deep and 37 m long, with 1.3 cm stretch mesh in the wings and 0.64 cm stretch mesh in the bag and is deployed from a skiff. It is set in a U shape from upstream to downstream along the channel edge. One person holds the upstream end of the net at the water’s edge while a second person backs the boat out perpendicular

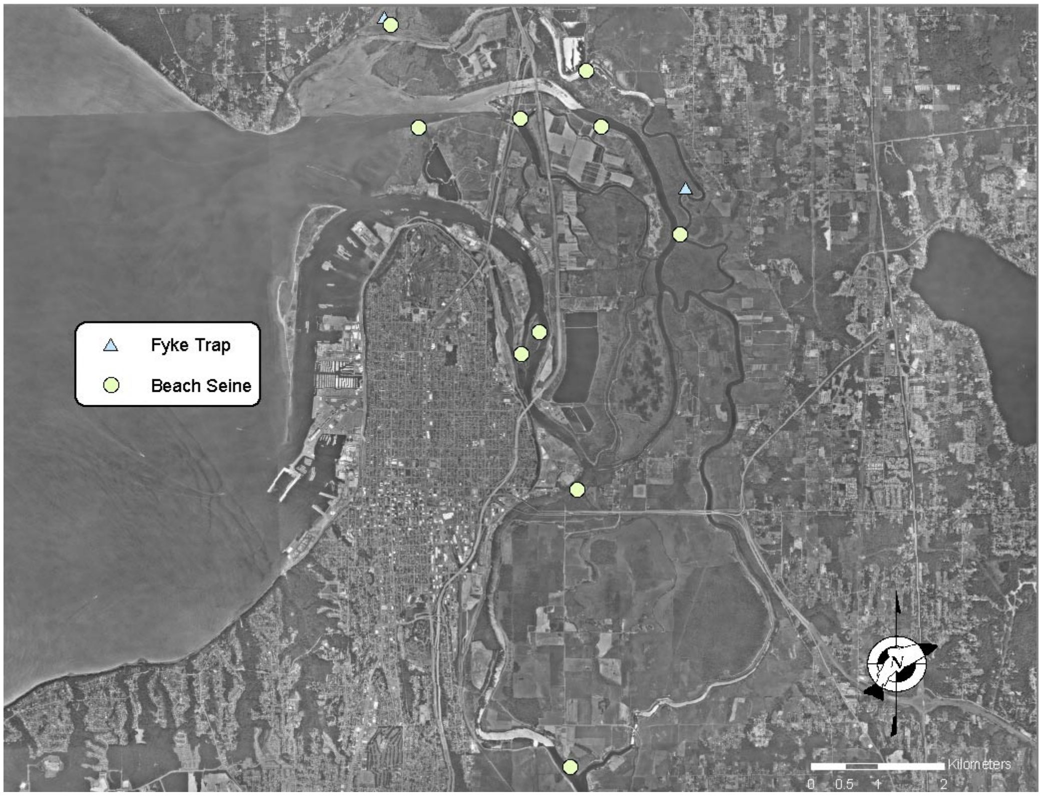

Figure 1. Snohomish River estuary showing beach seine and fyke trap sites sampled in 2002.

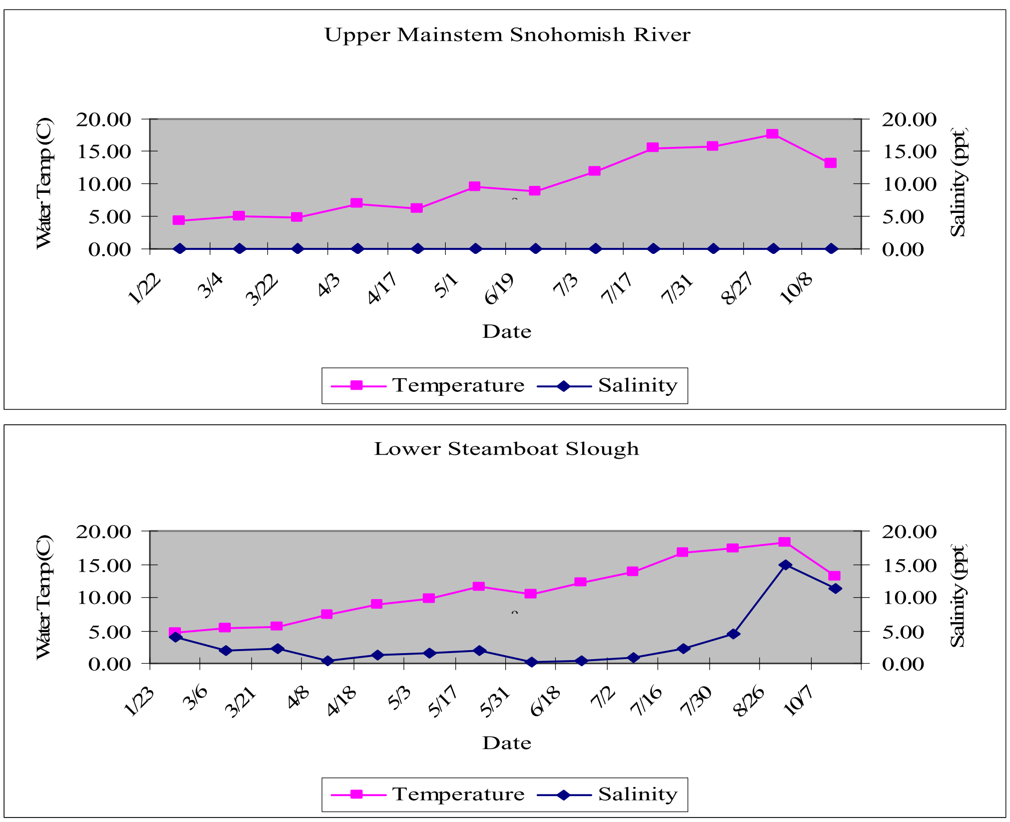

Figure 2. Temperature (°C) and salinity (ppt) gradients over time at uppermost and lowermost beach seine sample locations in the Snohomish River estuary, 2002.

to shore, turning and driving the net back to shore downstream. A third person helps guide the net out of the boat, and then jumps out of the boat at the downstream channel edge. Both people walk closer together while hauling in the net. The 'bag' is brought up and fish emptied into buckets for processing.

Both hatchery and wild chinook and coho salmon are caught in both fyke traps and beach seines. All hatchery chinook salmon released upstream of the estuary are internally marked with coded-wire tags (CWT) and/or externally marked with clipped adipose fins. In addition, juvenile chinook salmon released from the Tulalip Hatchery (in nearby Tulalip Bay) are otolith marked. It is not known whether fish released from the Tulalip Hatchery or from hatcheries in other river systems utilize the Snohomish River estuary for rearing after release. Future analysis of otoliths and DNA will help determine origin of fish utilizing Snohomish River estuary habitats. Most hatchery coho salmon are also CWT tagged and/or adipose fin marked and can be detected.

Results and Discussion

In 2002, we sampled the locations specified above to identify patterns in seasonal relative abundance, distribution, and migratory timing. Considerable effort was spent initially to determine how and where to effectively sample with the beach seine gear. Given the river current, presence of many snags, stepped and undercut banks, and vegetation along the channel edge, we determined sites could be sampled between tidal elevations of 0.3 and 2.1 m (mllw).

Catch

Preliminary observations from catch and length data for chinook and coho salmon in beach seine and fyke traps are presented, but data for other species captured has not been compiled. Further analyses on all salmonids and other species caught will be reported after completion of a second year of data collection.

<u>Chinook Salmon</u>

Wild and hatchery age 0+ chinook salmon were caught in beach seines. Few age 1+ chinook salmon were captured. Timing of age 0+ wild chinook salmon in the estuary peaked on May 31, and was widely spread out from mid-April through mid-July, and across all four distributary sloughs (Figures 3, 4). Hatchery origin age 0+ chinook salmon were released from Wallace River Hatchery on June 15, and these fish were detected in large numbers in the mainstem, and in smaller numbers in all distributary sloughs on June 18. They were still detected 2 weeks later, in higher abundance in Steamboat Slough than in other distributary sloughs, but were barely detected in the estuary after early July. Catch per unit effort (CPUE) was highest in the mainstem channel for both hatchery and wild 0+ chinook salmon during the peak migration period.

Chinook salmon catches at both fyke trap locations were small in comparison to what is considered to be primary habitat (Figures 5, 6). Both of these blind channels drain large tidal marsh areas. One consideration is that both trap locations were a distance upstream in the blind channels from their confluence with Ebey Slough in order to sample a smaller area and reduce the great numbers of non-salmonids captured during summer low-flow periods. Further investigations will be done to determine the extent to which salmonids penetrate into blind channels. We are currently sampling these blind channels very close to their confluence with Ebey Slough channels to evaluate the extent of marsh area that is actually utilized by salmonids (especially different species of salmonids).

<u>Coho Salmon</u>

Both age 0+ and age 1+ wild coho salmon were captured with the beach seine, though it is thought that the 1+ coho are capable of evading the beach seine to some extent, and they were not caught in large numbers (Figures 7, 8). An exception was one large catch of approximately 600 coho smolts in a single beach seine haul at a mainstem site on May 15 (Figure 7). Very few hatchery coho smolts were captured. Coho smolts were released from Wallace Hatchery on May 3, and our next sample date was May 15. Thus, we did not detect the hatchery release due to our sampling schedule. It is presumed that both wild and hatchery coho smolts migrate very quickly through the estuary. Regenthal (1954) provides the same observations regarding coho smolts.

Age 0+ coho were observed to be widely dispersed in both beach seine and fyke trap catches from April through the fall (Figures 5, 6, 8). They have been particularly prevalent in the Upper Ebey fyke trap location (Figure 5). This was surprising as it has been historically thought that these fish are displaced from upriver rearing areas due to high flows and/or limited upstream rearing carrying capacity and do not survive to return as adults (Regenthal 1954, Chapman 1962, Murphy et al. 1977). However, we observed these fish rearing and growing in the estuary throughout the year, though in very small numbers particularly through the winter. Miller and Sadro (2002) have recently documented this movement

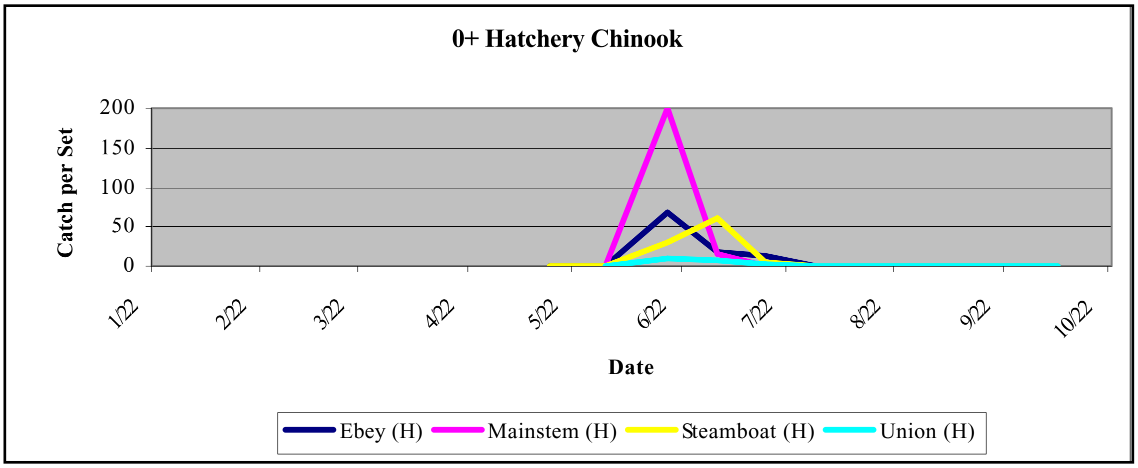

Figure 3. Catch per unit effort (CPUE) of age 0+ hatchery chinook salmon in beach seine sets in the Snohomish River mainstem and Union, Ebey and Steamboat sloughs.

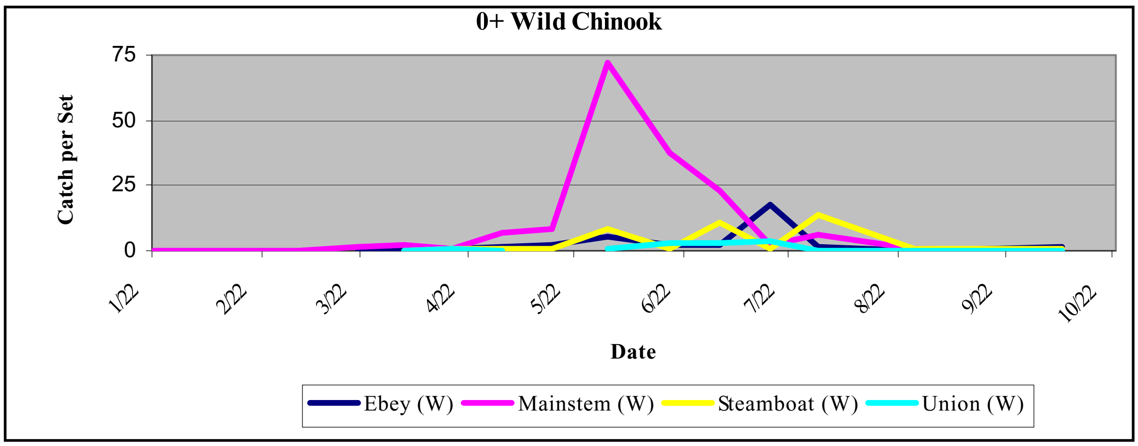

Figure 4. CPUE of age 0+ wild chinook salmon in beach seine sets in the Snohomish River mainstem and Union, Ebey and Steamboat sloughs.

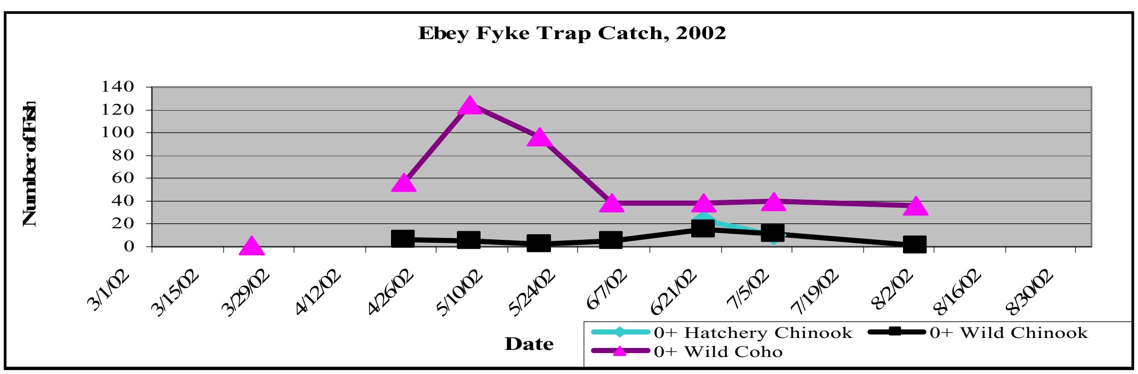

Figure 5. Fyke trap catch of age 0+ wild coho, and wild and hatchery chinook salmon at a blind slough on North Ebey Island, 2002.

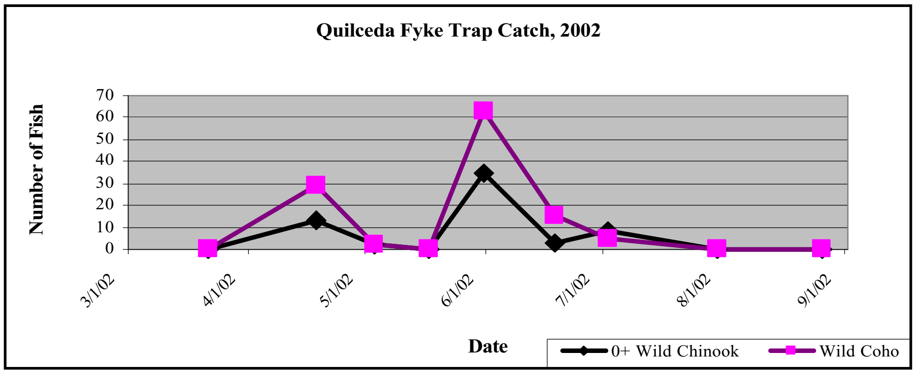

Figure 6. Fyke trap catch of age 0+ wild coho and chinook salmon at a blind slough near the mouth of Quilceda Creek, 2002.

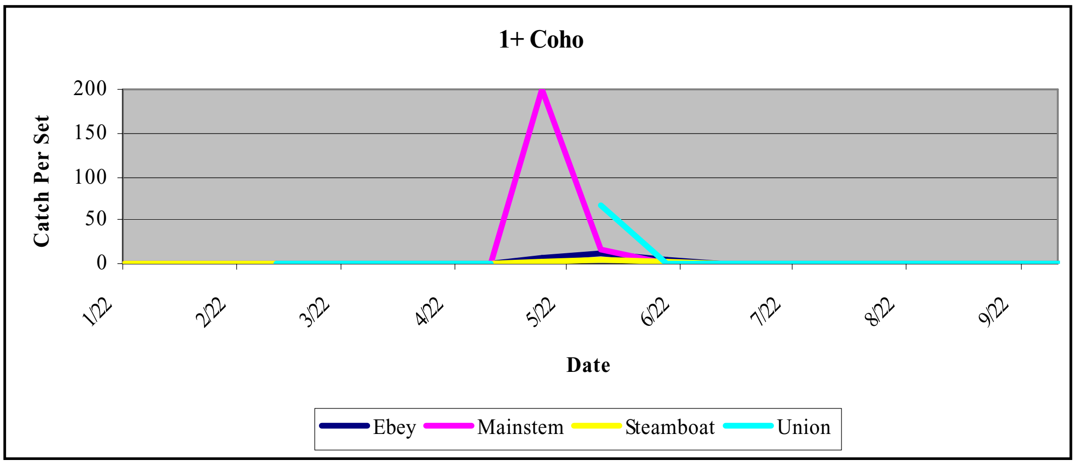

Figure 7. Catch per unit effort (CPUE) of age 1+ wild coho salmon in beach seine hauls in the Snohomish River mainstem and Union, Ebey and Steamboat sloughs, 2002.

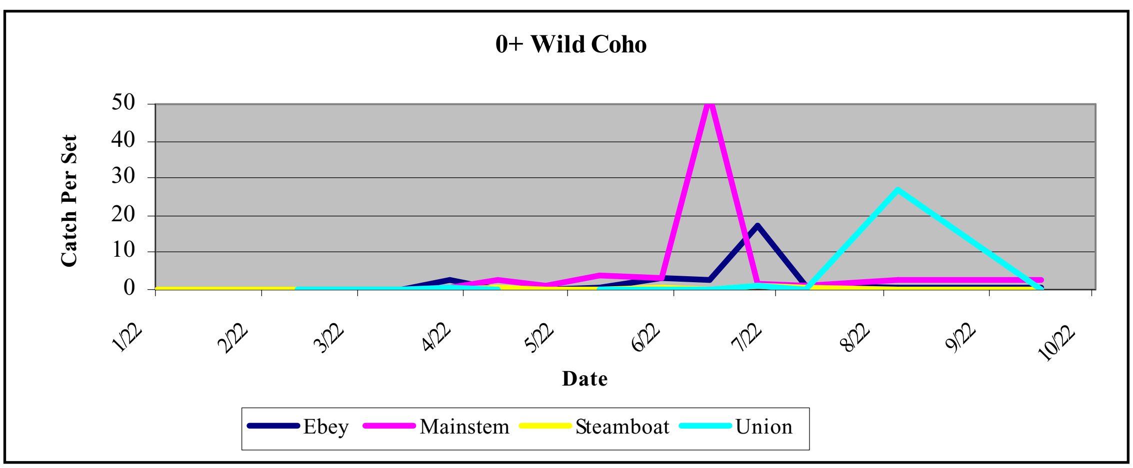

Figure 8. Catch per unit effort (CPUE) of age 0+ wild coho salmon in beach seine hauls in the Snohomish River mainstem and Union, Ebey and Steamboat sloughs, 2002.

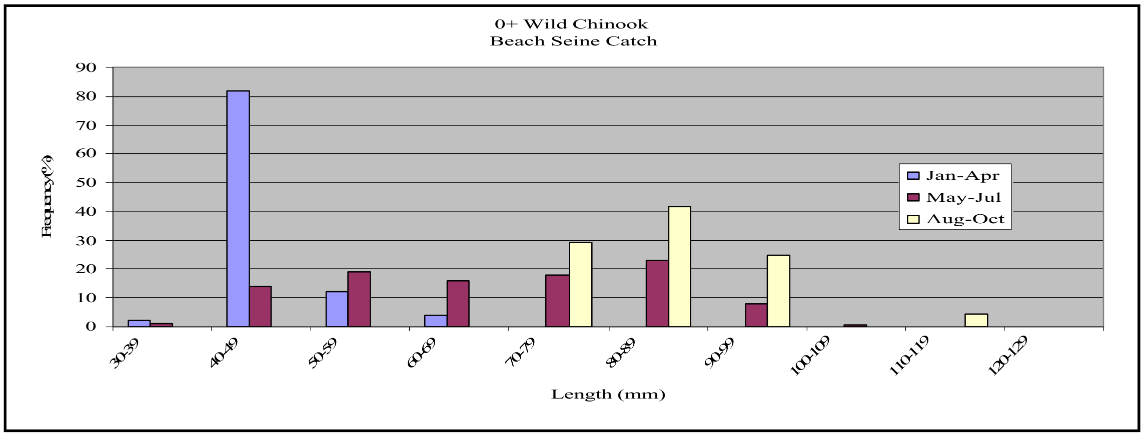

Figure 9. Length frequency distribution of age 0+ wild chinook salmon in beach seine catches in the Snohomish River estuary, 2002.

of coho in Winchester Creek, in coastal Oregon. They indicate that age-0 juvenile coho salmon move downstream into tidal freshwater/brackish estuarine habitats during summer and fall, and then move back upstream to overwinter in off-channel habitat marshes and tributaries. We did not fyke trap in blind channels in winter months in 2001 or 2002, but have observed that there is some opportunity for these fish to find refuge in these areas. Salinities in these tidal channels are relatively low, particularly during winter and high flow periods. Many tidal channels do not drain completely at low tides, and/or have residual pools that may provide refuge at low tide for overwintering coho salmon. Tanner et al. (2002) reported similar observations on nearby Spencer Island.

Size

Length frequency distributions indicate that early migrating chinook salmon enter the estuary soon after emergence at lengths that consistently range from 40 to 49 mm, from January through April (Figure 9). During peak migration months of May and June, the length distribution becomes much broader, ranging from 40 to 100 mm. There is slight evidence of a bimodal distribution in these fish during this time period, and it is not clear whether this represents two different life history patterns, or possibly different populations of chinook salmon. We have not conducted mark/recapture studies at this point in time to determine residence times, but we can make some inferences with the length-frequency data regarding rearing time in the estuary. A current hypothesis is that the larger fish (70-100 mm) may represent the early migrants that have been rearing and growing in the estuary, and that the smaller fish represent new migrant recruits into the estuary from upstream. Further work in 2003 and 2004 will improve our understanding of these life history patterns, growth and estuary residence. Length frequency in August to October indicates further growth of fish rearing in the estuary, and there is speculation that hatchery fish from other systems in Puget Sound may move into the Snohomish River estuary to rear. CWT data from collected specimens will provide new information regarding the extent of these movements.

Length frequency distribution of coho salmon in beach seine catches was generally broad during the peak migration period of May and June (Figure 10). There was an early pulse of very small fry that were likely displaced by high streamflow. Otherwise, as noted above, it was surprising that there was a consistent presence of young of the year juvenile coho in the estuary from spring through fall.

Future Work

Data collected in 2002 indicate that juvenile salmonids are distributed throughout the mainstem and three major distributary channels in the Snohomish River estuary. Several high beach seine catches in the mainstem indicate larger pulses of fish migrating during the peak migration down that system. Regenthal (1952) hypothesized that juvenile salmonid movement is largely dependent on dominant flow. Currently, the mainstem contains most of the flow and is primarily channelized along its length, with little opportunity for off-channel rearing. Most of the off-channel marsh sites available for juvenile salmonid rearing are located on Ebey and Union sloughs. All that exists for cover and vegetated habitat in the mainstem and Steamboat Slough is the "edge habitat." There is a great need to understand the importance of this habitat to migrating salmonids, particularly chinook salmon, and if it suffices for rearing and growth and saltwater acclimatization needs for the life history types that are dependent on slow-water estuarine habitats.

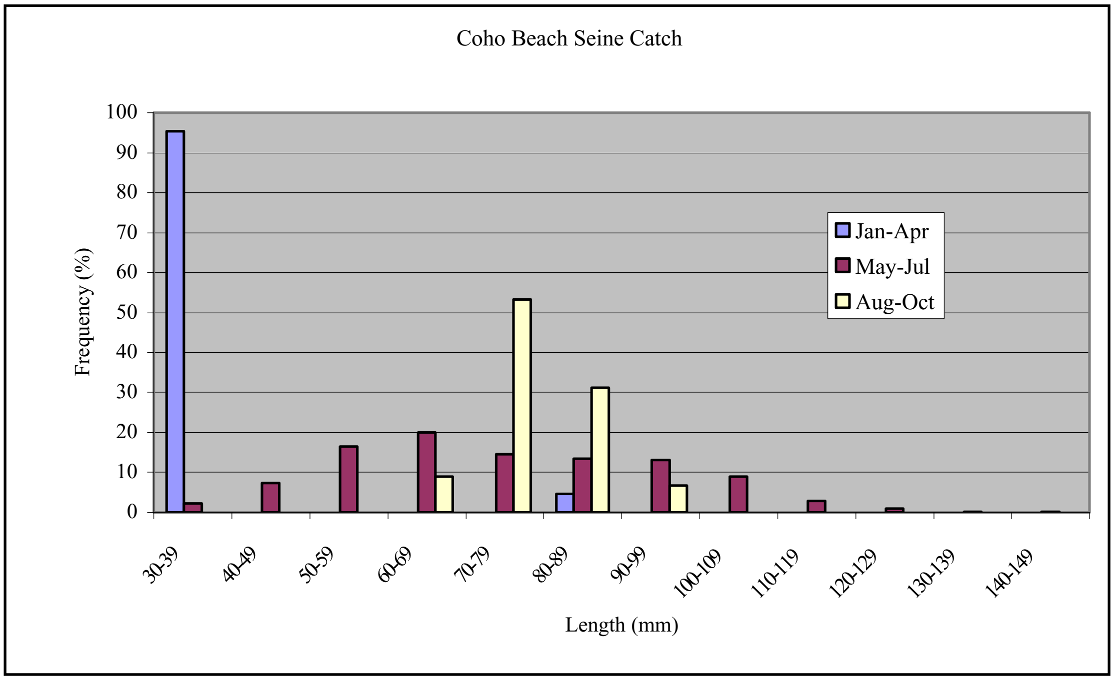

Figure 10. Length frequency distribution of coho salmon in beach seine catches in the Snohomish River estuary, 2002.

Ebey Slough is the least developed of the four channels and is one of few areas in Puget Sound where forested wetland complexes still exist. This is due to the lack of diking and conversion of marshland to agricultural land uses in a few locations along Ebey Slough. These areas are not extensive in the context of what existed historically (Haas and Collins 2001), but they represent what remains of this type of habitat today. In 2003 and 2004, we are extending the fyke trapping operations to include more sites, particularly in this forested wetland zone. We will be looking closely at comparing utilization of off-channel sites of various sizes and locations (upper vs. lower estuary, small vs. large) in the estuary to examine spatial structure of the chinook population in a landscape perspective, and at the quality of off-channel habitats (newly restored vs. reference) in terms of salmonid utilization, diet and growth. We also will begin to make comparisons between information collected in the Snohomish River estuary to the Skagit River estuary, and others, as regards juvenile salmonid habitat utilization. Understanding the importance of off-channel rearing habitats to salmonid survival in the contexts of quantity, quality, and spatial structure will help guide restoration and protection activities in Puget Sound to support recovery of wild chinook salmon populations.

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